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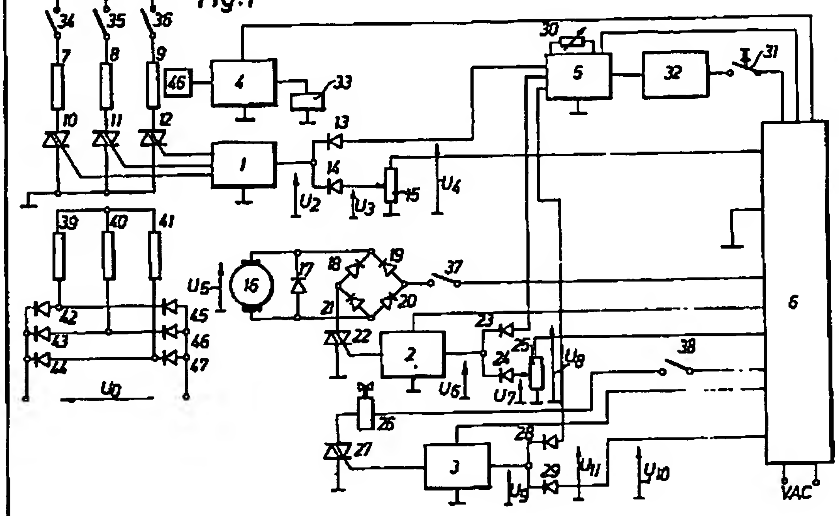
(54) Electronically controlled electric arc-welding

(57) An electronically controlled electric arc welding apparatus, particularly for metal arc-welding, includes a welding current supply transformer 7-9 and 39-41, an electric motor drive electrode feed mechanism 16 and triacs 10-12, 22 connected in series with primary windings 7-9 of the transformer and to a supply circuit of the electrode feed motor 16. These triacs control the welding current and the rate of electrode feed and for this purpose the triacs 10-12 are phase-controlled by means of control signals from a welding current control circuit 1 and the triac 22 is phase-controlled by a circuit 2 for controlling the rate at which the electrode is fed. The circuits 1 and 2 are themselves controlled by the application to them of the sum of a control signal obtained from a common control circuit 5 and a signal corresponding to a required welding current and the sum of a signal from the circuit 5 and a signal corresponding to a required rate of electrode feed, respectively. When used for gas-shielded metal arc welding, the apparatus also includes a phase-controlled triac 27 connected to an electric supply circuit of a solenoid-operated shielding gas supply valve 26.

Fig.1



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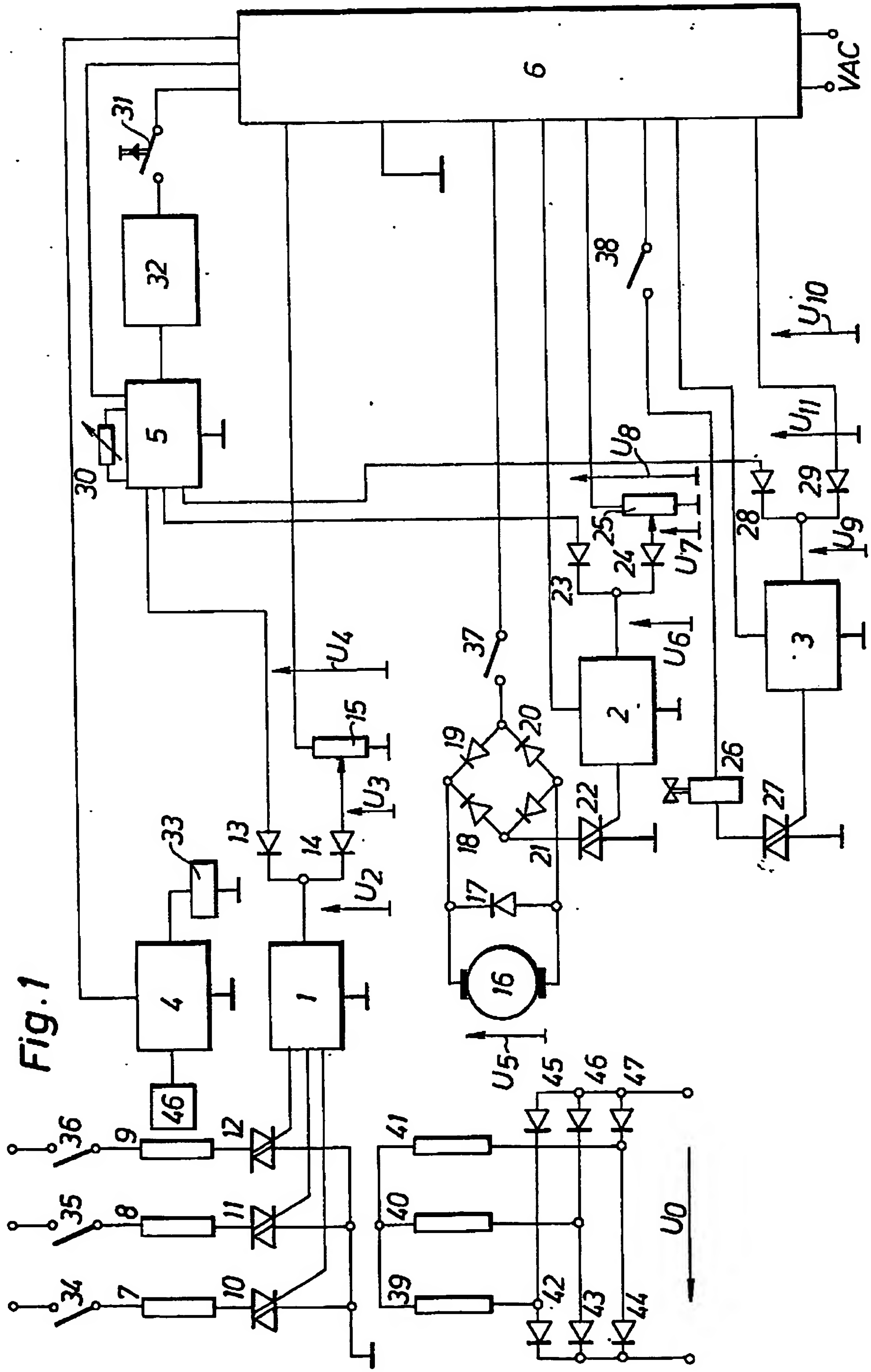
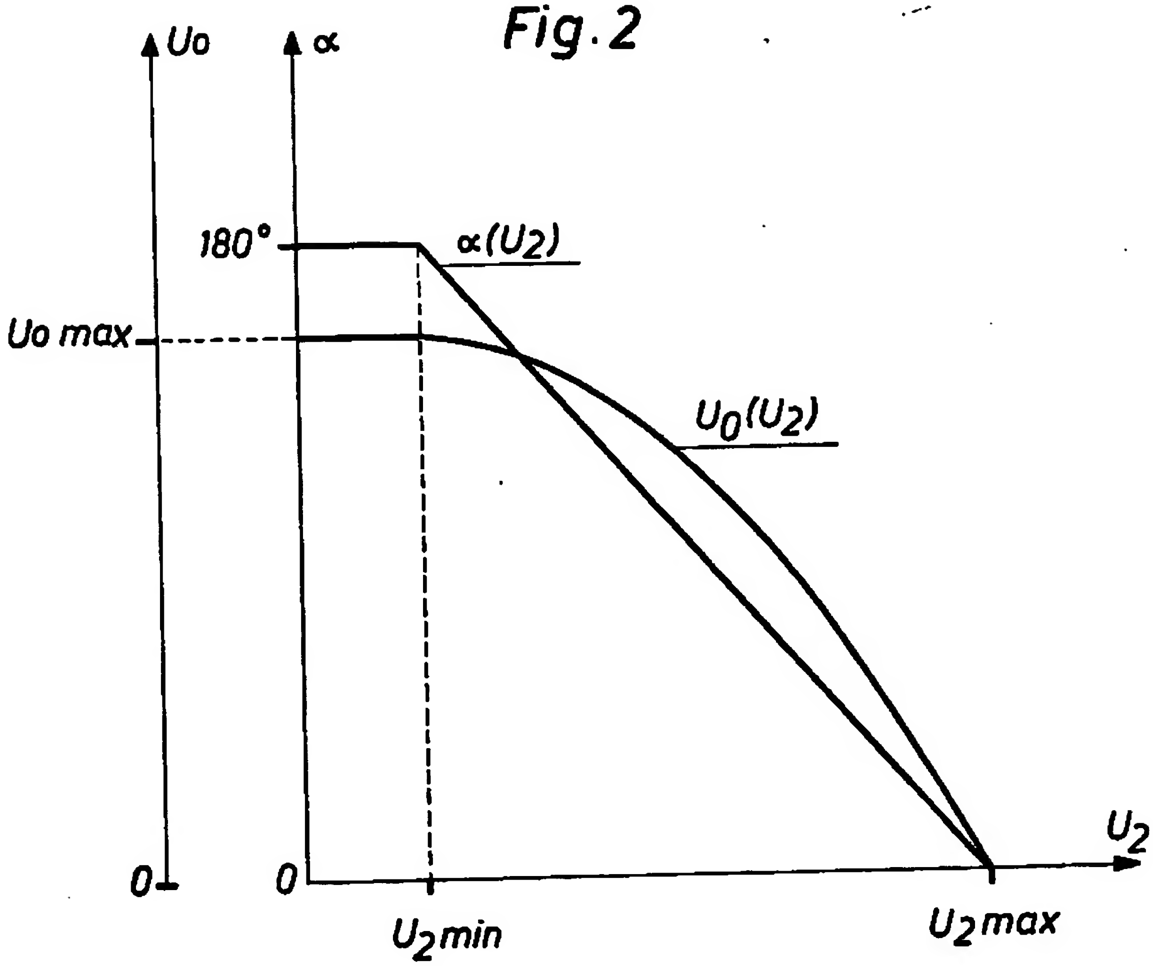
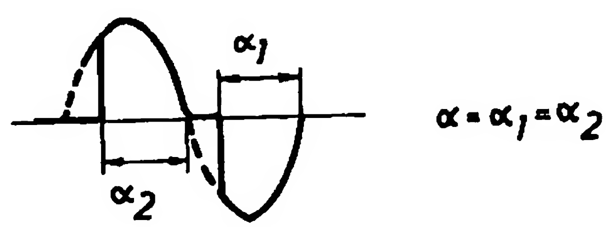


Fig.1

Fig. 2



$U_{2max} \approx U_{6max} \approx U_{9max}$



SPECIFICATION

Electronically controlled electric arc-welding

The present invention relates to a method of electronically controlling electric arc-welding apparatus, particularly apparatus for arc-welding metal, the apparatus including a transformer for supplying welding current and an electric motor-driven electrode-feed mechanism. The invention also relates to electric arc welding apparatus having an electronic control.

Many different systems for controlling the current in electric arc welding apparatus are known. Generally one of the following systems is used:-

1) A welding transformer having parallel magnetic circuits. This is an older system which was previously much used. With this system, however, the transformer is not effectively utilized when supplying a low welding current. The efficiency and power factor is thus low.

2) Series choke. In this system, each phase of a 3-phase transformer is coupled in series with a regulated or controlled inductance. This is an unsatisfactory solution, particularly with respect to the energy losses.

3) Welding rectifiers having three thyristors and three diodes. Although such a system enables the welding current to be controlled, the range in which the current can be regulated is limited.

4) Welding rectifiers including six thyristors. This system enables the current to be regulated within a wide range. With respect to the coupling of the thyristors, however, it is necessary to use special transformers and separate control systems for each thyristor, and this makes this particular system expensive.

5) Tapped transformers. This is a commonly used system. In this system however, it is necessary to make changes in the welding transformer and, for the purpose of reducing the welding current in a controlled manner, the primary winding must be made larger, which increases the dimensions of the transformer and the cost. In order to provide a plurality of regulating posibilities, it is also necessary to use asymmetric couplings, which in turn, among other things, cause the mains network supplying the transformer to be subjected to non-symmetrical loads. Because of the asymmetric output of current from the mains, the transformer is not utilized to the full, which means that the transformer must, to a certain extent, be overdimensioned.

Gas-shielded metal arc-welding (MIG) is a modern method of joining steel and non-ferrous metals and alloys. The quality of the welds obtained with this method depends upon the exactness with which the welding parameters can be selected, particularly such parameters as welding current, the rate of feed of the electrode and the length of time over which the shielding gas is supplied. Also, the duration of the welding current and of the electrode-feed are important when spot-welding or intermittent welding is carried out.

Existing welding apparatus for the arc-welding of metal, and in particular for gas-shielded arc-welding of metal, includes a plurality of relays and switches which are used for energizing a welding current supply means, an electrode feed mechanism and means for supplying the shielding gas. Relays and switches have certain limitations, inter alia with respect to the exact synchronisation of different devices in the welding apparatus. Further, they have a limited reliability and a limited switching rate. Hence these relays and switches are not suited for apparatus intended for precision welding, which requires a high degree of reliability.

The main object of the present invention is to provide a method of electronically controlling an electric arc-welding apparatus, particularly an arc-welding apparatus for welding metal, and electric arc-welding apparatus incorporating an electronic control for carrying out the method, wherein the aforementioned disadvantages are at least largely overcome, wherein the welding current is enabled to be continuously regulated in a simple and exact fashion from zero up to a maximum value while maintaining a substantially symmetrical load on all current supply phases, and wherein an electrode-feed mechanism is enabled to be energized and de-energized in dependence upon the supply of welding current.

To this end, according to this invention, in a method of electronically controlling an electric arc-welding apparatus having a multi-phase welding current supply transformer and an electric motor-driven electrode feed mechanism, the welding current from the transformer and the rate of electrode feed are controlled by means of triacs connected one in series with each of the primary windings of the transformer and one in a supply circuit of the electrode feed motor, the triacs in series with the primary windings being phase-controlled by means of control signals from a welding current control circuit and the triac in the motor supply circuit being phase-controlled by means of control signals from a circuit for controlling the rate of electrode feed, and the signals from the control circuits are controlled by applying to the welding current control circuit the sum of a control signal obtained from a common control circuit and a signal corresponding to a required welding current and by applying to the electrode feed control circuit the sum of a control signal obtained from the common control circuit and a signal corresponding to a required electrode feed rate.

By the use of triacs controlled in this way, it is possible to regulate the welding-current symmetrically and continuously from zero up to a maximum value, and to synchronize the speed increase of the electrode feed motor as this is controlled in a corresponding manner.

In gas-shielded electric arc welding, the supply of shielding gas is controlled by means of a further triac connected in the electrical circuit of a solenoid-operated valve which controls the gas-supply, the further triac being phase-controlled by means of control signals from a gas supply control circuit, the signals from the gas supply control circuit being controlled by applying to the circuit a control signal obtained from the common control circuit.

The invention also consists, according to another of its aspects, in an electric arc-welding apparatus having a multi-phase welding current supply transformer, an electric motor-driven electrode feed mechanism, and an electronic control comprising triacs connected one in series with each of the primary windings of the transformer and one in a supply circuit of the electrode feed motor, the triacs being arranged to control the welding current and the rate of feed of the electrode, a welding current control circuit connected to the triacs in series with the primary windings, and a circuit for controlling the rate of feed of an electrode connected to the triac in the motor supply circuit, the control circuits being arranged to generate phase-control signals for controlling the triacs, a common control circuit, and means for applying to the welding current control circuit the sum of a control signal obtained from the common control circuit and a signal corresponding to a required welding current and for applying to the feed rate control circuit the sum of a control signal obtained from the common control circuit and a signal corresponding to a required electrode feed rate.

The common control circuit is preferably arranged so that the control signals from it can only take two values, one of which causes the signals in the form of ignition pulses from the related control circuits to the triacs to be blocked and the other of which, in the absence of any other signal added thereto, would cause the related control circuits to produce signals which would cause the triacs to adopt their maximum conductive angles, the other value only being generated when a start contact value only being generated when a start contact is actuated.

The apparatus in accordance with the invention preferably also comprises selector means for selecting different working modes of the apparatus, the selector means co-operating with the common control circuit to generate control signals which select the working mode of the apparatus. The signals corresponding to the required welding current and the required rate of electrode feed, respectively are suitably able to be varied by means of respective potentiometers.

A triac is defined for the purpose of the aforegoing and the following description and claims, as a controlled semi-conductor device having a characteristic corresponding to that obtained with a bidirectional thyristor.

An example of a method and of apparatus in accordance with the invention will now be described with reference to the accompanying drawings in which:-

Figure 1 is a block circuit diagram of a gas-shielded electric arc-welding apparatus for welding metal; and,

Figure 2 shows two graphs illustrating the mode of operation of control circuits incorporated in the apparatus of Figure 1.

The apparatus shown in Figure 1 comprises a 3-phase welding transformer having primary windings 7, 8 and 9, and secondary windings 39, 40 and 41. Rectifier diodes 42 to 47 are coupled to the secondary windings, which provide a resultant welding voltage output U_0. Connected in series with the primary windings 7 to 9 are triacs 10, 11, and 12 respectively, these triacs being phase-controlled from a welding current control circuit 1. A direct current shunt motor 16 controls the electrode feed, the rotational speed of the motor 16 being controlled by varying the voltage U_6 across the motor. The motor is coupled to the direct current output of a rectifier bridge comprising diodes 18 to 21. Connected in parallel with the motor is a damping diode 17. A triac 22 is connected in series with the alternating current input of the rectifier bridge and is phase-controlled from a control circuit 2 which controls the rate of feed of the electrode.

As the welding apparatus is intended for gas-shielded electric arc-welding, it also includes an electromagnetically controlled valve 26 for supplying shielding gas. Connected in the circuit controlling the shielding-gas supply valve 26 is a triac 27, which is phase-controlled from a gas-supply control circuit 3.

A feed voltage block 6 is provided, inter alia, to supply a protective circuit 4, which in turn controls a contactor or a relay 33. Arranged within the primary winding 9 of the transformer is a temperature sensor 48. When the temperature in the winding 9 exceeds a permitted maximum value, a signal is sent to the protective circuit 4, which then immediately breaks the current supply to the relay or contactor 33. The relay 33 then opens its contacts 34, 35 and 36 in the three current supply phases to the transformer and also opens contacts 37 and 38, which interrupts the current supply to the electrode feed motor 16 and to the solenoid valve 26 respectively. This interruption in the current supplies shuts down the welding apparatus and protects the transformer against overheating and destruction.

The aforementioned control operations using the various triacs will now be described in more detail. Voltages U_2, U_8, and U_9 are applied to the control circuits 1, 2 and 3 respectively, and the gate electrode of each triac is controlled by ignition pulses generated by the respective control circuit. The ignition pulses for each triac are phase-delayed relative to the main feed voltage, the magnitude of the delay determining the conducting angle α for the respective triac. Adjustment of the conducting angle α is obtained by varying the control voltage U_2, U_8 or U_9 applied to the control circuit. The maximum conducting angle corresponds to the lowest control voltage.

Figure 2 illustrates the relationship between the voltage U_2 applied to the control circuit 1 and the conducting angle α for the triacs connected to the primary windings of the transformer, and the resultant rectified voltage U_0-U_{2max} represents the control voltage corresponding to total blocking of the ignition pulses to the triacs. Both the conducting angle α and the voltage U_0 are then zero. When U_2 decreases to U_{2min}, the conducting angle increases towards 180° per half period and the D.C. voltage U_0 increases towards U_{0max}.

The control voltage U_2 is the resultant voltage obtained at the output of a diode adder comprising diodes 13 and 14. A voltage U_3 is applied via the

diode 14, and this voltage is set by means of a potentiometer 15 and can vary from zero up to U_{2max}. A control voltage U_4, which is generated in a control circuit 5, is applied via the diode 13. The control signal U_4 can take either of only two values, U_4=zero and $U_4>U_{2max}$. Thus, two functional states can prevail in dependence upon the value of the control voltage U_4:

1) When the voltage U_4 is zero, the voltage U_2 is then equal to the voltage U_3, it thus being possible to adjust the conductive angle of the triacs between 0 and the maximum value, by means of the regulating potentiometer 15.

2) When the voltage $U_4>U_{2max}$, the voltage U_2 is then greater than U_{2max}, which means that the ignition pulses to the triacs 10, 11 and 12 are blocked.

In order to make the control circuit 5 operative, it is necessary to press a start button 31 on the welding apparatus and thereupon the signal U_4=zero is obtained. A selector switch 32 decides the function mode in which the control circuit 5 will operate when the button 31 is pressed. Thus, it is possible with the apparatus, in addition to carrying out continuous welding operations, also to perform, for example, spot welding, intermittent welding or pulsation arc welding. In this respect, a variable resistor 30 is arranged to control the duration of the pulses during spot welding and intermittent welding.

The control circuit 2 for controlling the triac 22 in the supply circuit of the elctrode feed motor 16 operates in a manner corresponding to that of the control circuit 1. The input of the circuit 2 receives the voltage U_6 from a diode adder comprising the diodes 23 and 24. This voltage determines the conducting angle of the triac 22 in the same manner as the control voltages U_2 on the control circuit 1 determines the conducting angle of the triacs 10 to 12. The speed determining voltage U_5 across the motor is thus dependent upon the control voltage U_6. A voltage U_7, which is applied via the diode 24, is set by means of a potentiometer 25 and can vary from zero up to U_{6max}, this latter value being that which will block the ignition pulses to the triac 22. A control signal U_8 from the control signal circuit 5 is applied via the diode 23. This signal can take only two values U_8=zero and $U_8>U_{6max}$, and consequently only two functional modes can be obtained depending upon the value of the control voltage U_8. In one mode, when $U_8>U6_{max}$, the triac 22 is fully blocked, and in the other mode, when U_8 is zero, the conducting angle of the triac 22 is determined by the setting of the potentiometer 25. The value U_8=zero is obtained when the start button 31 is pressed.

The triac 27 connected in the supply circuit of the solenoid valve 26 is controlled in dependence on the control voltage U_9, which is provided by the output of a diode adder comprising the diodes 28 and 29, and which is applied to the control circuit 3. A constant voltage U_{10}=zero is applied via the diode 29, while a control signal $U_1 1$ from the control circuit 5 is applied via the diode 28. The control signal U_{11} can only take two values, U_{11}=zero and $U_{11}>U_{8max}$, and the control voltage U_8 can therefore also have only two values: U_9=zero and $U_9>U_{8max}$. The first of these values corresponds to the maximum conductive angle of the triac 27 and causes the valve 26 to open. The other value corresponds to full blocking of the ignition pulses, causing the valve to be closed. The control voltage U_{11}=zero is obtained when the start button 31 is pressed.

Thus, with the aforedescribed circuit arrangement the welding voltage, electrode feed rate, and shielding gas supply are exactly synchronized with the aid of control signals from the control circuit 5, the working cycle of which is dependent upon the setting of the selector switch 32. The magnitude of the welding current is adjusted by means of the potentiometer 15 and the speed at which the electrode is fed is adjusted by means of the potentiometer 25. Optionally, the voltages from the potentiometers 15 and 25 can be varied in dependence upon one another. Control of the shielding gas supply valve can be omitted when no shielding gas is to be used in the welding operation, without it being necessary to change the circuitry in other respects. The invention permits the welding current and the speed at which the electrode is advanced to be very finely regulated, and no problems or disadvantages resulting from asymmetric loads on the welding transformer are encountered. The same apparatus can also be adapted to different welding procedures, which can readily be set or adjusted by means of the selector switch 32.

CLAIMS

1. A method of electronically controlling an electric arc welding apparatus having a multi-phase welding transformer and an electric motor driven electrode feed mechanism, wherein the welding current from the transformer and the rate of electrode feed are controlled by means of triacs connected one in series with each of the primary windings of the transformer and one in a supply circuit of the electrode feed motor, the triacs in series with the primary windings being phase-controlled by means of control signals from a welding current control circuit and the triac in the motor supply circuit being phase-controlled by means of control signals from a circuit for controlling the rate of electrode feed, and the signals from the control circuits are controlled by applying to the welding current control circuit the sum of a control signal obtained from a common control circuit and a signal corresponding to a required welding current and by applying to the electrode feed control circuit the sum of a control signal obtained from the common control circuit and a signal corresponding to a required electrode feed rate.

2. A method according to claim 1 for controlling a gas shielded electric arc welding apparatus, wherein the supply of shielding gas is controlled by means of a further triac connected in the electrical circuit of a solenoid-operated valve which controls the gas supply, the further triac being phase-controlled by means of control signals from a gas supply control circuit, the signals from the gas supply control circuit being controlled by applying to the circuit a control signal obtained from the common control circuit.

3. An electric arc welding apparatus having a multi-phase welding current supply transformer, an electric motor driven electrode feed mechanism, and an electronic control comprising triacs connected one in series with each of the primary windings of the transformer and one in a supply circuit of the electrode feed motor, the triacs being arranged to control the welding current and the rate of feed of the electrode, a welding current control circuit connected to the triacs in series with the primary windings, and a circuit for controlling the rate of feed of an electrode connected to the triac in the motor supply circuit, the control circuits being arranged to generate phase-control signals for controlling the triacs, a common control circuit, and means for applying to the welding current control circuit the sum of a control signal obtained from the common control circuit and a signal corresponding to a required welding current and for applying to the feed rate control circuit the sum of a control signal obtained from the common control circuit and a signal corresponding to a required electrode feed rate.

4. Apparatus according to claim 3 for gas shielded arc welding of metal, the apparatus comprising a further triac connected in a supply circuit of a solenoid-operated valve which controls the supply of shielding gas, a gas-supply control circuit for generating phase-control signals for the further triac, and means for applying a control signal obtained from the common control circuit to the gas supply control circuit.

5. Apparatus according to claim 3 or claim 4, wherein the control signals from the common control circuit are of only two values one of which causes the signals in the form of ignition pulses from the related control circuits to the triacs to be blocked and the other of which, in the absence of any other signal added thereto, would cause the related control circuits to produce signals which would cause the triacs to adopt their maximum conductive angles, the other value only being generated when a start contact is actuated.

6. Apparatus according to claim 5, comprising selector means for selecting different working modes of the apparatus, the selector means co-operating with the common control circuit to generate control signals which select the working mode of the apparatus.

7. Apparatus according to any one of claims 3 to 6, wherein the signals corresponding to the required welding current and to the required rate of electrode feed are variable by means of respective potentiometers.

8. A method according to claim 1, substantially as described with reference to the accompanying drawings.

9. Apparatus according to claim 3, substantially as described with reference to the accompanying drawings.

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